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Abstract

DIFFUSION BONDING OF URANIUM WITH MAGNESIUM BY MEANS OF INTERLAYERS

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Due to mutual solid state immiscibility of uranium and magnesium the bonding of these metals without a high joint deformation is impossible.

The present report describes the results of experimental diffusion welding of uranium with magnesium by means of thin intermediate layers. For these interlayers were chosen metals with low thermal neutron absorption cross-sections: zirconium, aluminium, nickel and copper; their metallurgical properties permit to assume a diffusion interaction with uranium as well as magnesium. Zirconium and aluminium were used in the form of foils, nickel and copper and were deposited electrolytically on uranium. The interlayer thickness was usually 15μ . The samples (pellets) of uranium - interlayer - magnesium were welded by diffusion at a constant initial compression and at various temperatures and times of annealing. The weld quality was investigated by measuring the sliding weld strength (at ambient and elevated temperatures) and by the methods of optical metallography.

During the interdiffusion of zirconium with uranium and magnesium in the range from 500°C to 590°C limited solid solutions of uranium and magnesium in zirconium were predominantly formed. The sliding weld strength after diffusion annealing attained values up to 300 kg/cm^2 or even more (at ambient temperature). This weld strength was conserved even after a long-time heating (810 hours) at 500°C . The strength of the U-Zr-Mg weld at a temperature of 500°C attained approximately 45 kg/cm^2 . This strength practically also did not change with the long-time annealing mentioned above.

Aluminium interlayers yielded different results according to the thickness of the foil used. During a diffusion treatment in the range of $410\text{--}500^{\circ}\text{C}$ the growth of intermetallic compounds of uranium with aluminium is

very intensive. An aluminium interlayer of a thickness of 8μ reacts throughout with uranium sooner than any considerable interaction with magnesium takes place. The welds produced in this way showed a sliding strength of nearly 500 kg/cm^2 , which did not change with a long-time heating. The strength at 500°C attained in this case values up to 70 kg/cm^2 . Thicker aluminium interlayers (40 to 80μ) from a number of solid solution and intermetallic phases layers at the interface with magnesium; at the welding temperature over 437°C an eutectic alloy layer is formed. The weld strengths are determined here predominantly by the properties of these phases. The undereutectic diffusion layers showed at room temperature a sliding strength of approximately 130 kg/cm^2 , the eutectic alloy over 500 kg/cm^2 . At the temperature of 500°C , however, the weld strength is minimal due to the presence of a liquid phase. After a long time heating at 500°C considerable part of aluminium which is not bound on uranium enters the solid solution with magnesium without affecting essentially the weld strength.

The characteristics of uranium welds with magnesium using nickel and copper intermediate layers are very similar. At a short-time diffusion heating below the eutectic temperature (507°C for the Ni-Mg system and 485 for that of Cu-Mg) diffusion layers were obtained with a sliding strength of approximately 200 kg/cm^2 . At a supereutectic temperature annealing predominated at the interface an eutectic alloy, which showed the strength up to 400 kg/cm^2 at room temperature. During a long-time heating at about 500°C this strength still somewhat improves, but the eutectic alloy quickly penetrates along the magnesium grain boundaries and thus seriously deteriorates the properties of the canning material.

These results show that sufficiently strong and long-time stabile magnesium to uranium diffusion bonds may be attained by means of thin aluminium (approximately 8μ) and zirconium intermediate layers.

The experiments carried out have proved the dependence of the bond strength on temperature and time of diffusion treatment. Assuming the bond strength dependence on the diffusion transfer of a certain amount of mass necessary for forming a cohesive intermediate region between the joined crystal lattices a relation has been derived which describes the time-temperature dependence of the bond strength. The validity of this relation was checked experimentally for the sliding strength of the U-Zr-Mg bonding, which could be investigated in broader ranges of diffusion treatment temperatures and times.